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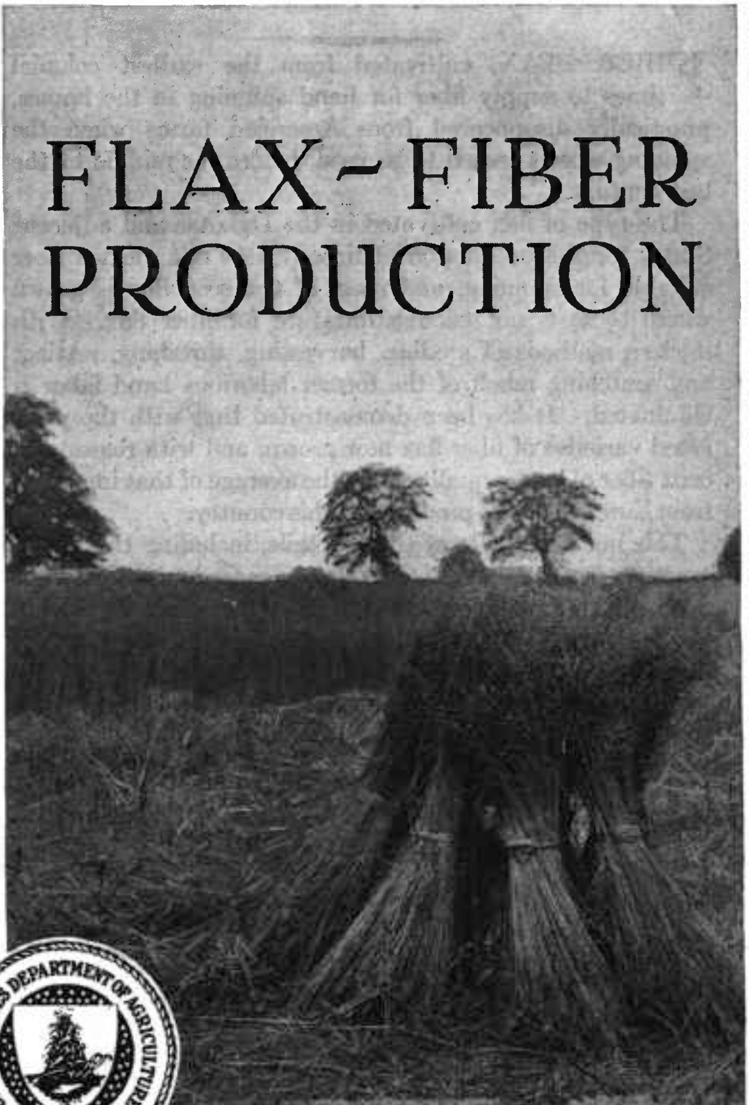
FLAX-FIBER PRODUCTION



FIBER FLAX, cultivated from the earliest colonial times to supply fiber for hand spinning in the homes, practically disappeared from American farms when the spinning wheels ceased to be used, before the middle of the last century.

The type of flax cultivated in the Dakotas and adjacent States for the production of linseed does not yield a fiber suitable for spinning, and most of the seed flax is grown where there is not enough moisture for fiber flax. With modern methods of seeding, harvesting, threshing, retting, and scutching much of the former laborious hand labor is eliminated. It has been demonstrated that with the pedigreed varieties of fiber flax now grown, and with reasonable care, fiber of better quality than the average of that imported from Europe may be produced in this country.

This bulletin treats of these details, including the rather exacting requirements of fiber flax in regard to soil and climate. These requirements of soil and especially of climate should be carefully considered before undertaking the cultivation of fiber flax in new areas. With less than 20 flax-spinning mills in the United States, the market for flax is limited.

This bulletin is a revision of and supersedes Farmers' Bulletin 669, Fiber Flax.

Washington, D.C. Issued, July 1934

FLAX-FIBER PRODUCTION

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INTRODUCTION

THE PURPOSE of this bulletin is to give information about the best methods for producing flax fiber. Increased yields and fiber of very good quality have been produced on a small scale in experiments, and it is believed that the application of similar methods to commercial field practice may give similar results. There is nothing essentially new in the recommendations, and no particular increase in labor or skill will be required to carry out the work.

Many samples of fiber have been produced in the United States that compared favorably with the best grades of Irish and even Belgian Courtrai flax, but these have been only samples. In recent years flax fiber of excellent quality has been produced in commercial quantities in Oregon, but in many cases there is still room for improvement. It is not probable with American machine methods and the present development of flax-fiber machinery that the very high grades of fiber will be produced, such as are produced by the skilled hand laborers of Europe. It is believed, however, that with better knowledge of the work, avoiding waste efforts and applying labor to better advantage, fiber much better than the present average quality may be produced. The improved varieties of fiber flax will certainly give larger yields and more uniform fiber than may be expected from imported varieties or seed of uncertain origin, but even if improved varieties are grown the proper cultural methods should be employed to realize best results.

HISTORY OF FIBER FLAX IN THE UNITED STATES

Flax was one of the first crops grown by the Cavaliers at Jamestown and by the Pilgrims at Plymouth. In the early colonial days nearly

every farmhouse had its spinning wheel, and the women were skilled in the art of spinning fine linen and woolen yarns. It was necessary for the farmers to raise flax, as it was the chief textile used in making their homespun clothes. The farmers deseeded the flax in the field by drawing the seed-bearing ends of the straw through large wire combs, a process called rippling. After deseeding, the straw was mostly dew retted, although sometimes it was water retted. After the straw had been retted, hand brakes were used by the men to break the straw. These brakes were made of heavy wooden slats set edgewise in a frame with other slats crushing the flax straw down between them. In some cases the straw was broken first on an open brake and then on a closed brake. The difference between the two was the closeness of the slats. After it had been broken, the men scutched the fiber with a swingling block and knife to beat out the small pieces of wood from the fiber. This was hard work and much slower than our methods today.

The culture of flax was much encouraged in nearly all of the Colonies north of the Carolinas, and the people became greatly skilled in the different arts of its preparation. Many homes had small hand looms for weaving, and later larger looms took the place of some of the smaller ones. At the close of the eighteenth century there were numerous small scutching mills in the Northeastern States, but the invention of the cotton gin in 1793 and the cheaper production of cotton soon did away with most of the flax-scutching mills. In New York many of these mills continued nearly through the nineteenth century but gradually ceased operation. In Michigan and western Ontario an important fiber-flax growing center was developed, and this industry has never been entirely discontinued. The name of James Livingston will be remembered in connection with the pioneer production of fiber flax in Michigan and western Ontario. At one time he owned and operated 18 scutching mills, 6 in Michigan and 12 in western Ontario. His company also employed 40 to 60 hacklers during the years 1887 to 1910 at Yale, Mich. Although the industry is still in the hands of relatives of James Livingston, it has declined until now less than 1,000 acres of fiber flax are produced annually by his descendants.

CLIMATIC RELATIONS

Without a suitable climate for the production of fiber flax it is useless to expect to be successful even though one selects the best land and seed and follows the best practices in the culture. It is doubtful whether there is another general agricultural crop that responds so well to a favorable climate as fiber flax. Seed flax may be raised under a fairly wide range of conditions, but fiber flax should be planted only in sections where climatic conditions are favorable and where previous experiments or crops have given favorable results. Seed flax is produced largely in North Dakota, South Dakota, Minnesota, Montana, and Wyoming, where the climate is too dry for fiber flax. If grown under dry conditions fiber flax is likely to be short and woody, containing a harsh dry fiber. The fiber-flax plant requires abundant moisture and cool weather during the growing season. Moisture well distributed in many light showers is much better than in downpours. Ideal locations for the production of fiber flax are found around the Great Lakes where the fogs and dews

supply moisture in addition to rains. Cool, moist weather from March to June followed by warm, dry weather in July, and the absence of storms that will cause lodging, give excellent climatic conditions for fiber flax in the Willamette Valley in Oregon and in the Puget Sound region in Washington.

Cloudy days are much desired during the growth of the flax, as they help lower the temperature and conserve moisture. After the plant has reached a certain stage in its growth, a hot, dry day may cause it to branch and later produce seed. If the weather does not turn warm the plant continues to grow, not indefinitely but for a longer period. The flax grower as well as the scutching-mill operator should remember that every inch added to the stem below the lowest branches brings more profit. To the farmer it means a greater tonnage of straw and to the millman a longer and higher yield of fiber as well as a straw with a higher percentage of fiber. The fiber of commercial value exists only in the straw from the ground to the lowest branches or beginning of the panicle. The small amount of fiber in the panicle is lost usually in the processes of breaking and scutching, and the root contains no fiber.

Although a cool, moist season is desired during the growing period, warm, dry weather is best for curing the seed after the growth of the stalk as well as for threshing and for drying the straw after retting, especially if water-retting is practiced. Where dew-retting is practiced, there must be sufficient moisture during this period to ret the straw.

In the flax-growing region in Oregon the climate is especially adapted for the production of fiber flax if the seed is planted early. There is usually abundant moisture in March, April, May, and early June, and the dry weather in late June and July cures the flax to a golden yellow, producing a very strong but slightly harsh fiber. The retting is done in tanks, and usually there is excellent weather for drying the retted straw as rains are infrequent from the middle of June to the latter part of September. The climatic conditions for flax-fiber production in the Willamette Valley are believed to be equal to those found in the fiber-flax regions of Europe.

SELECTION OF SOIL

There are two very essential factors in the success of a fiber-flax crop over which the farmer has some control. (1) The selection of a soil type suitable for fiber-flax production, and (2) the planting of the seed sufficiently early to attain a good quality of fiber as well as a high yield. Soil type not only influences the yield of flax but also influences to a very large extent the quality of the fiber in the straw. In European countries the common practice is to keep the flax produced in each small field separate, in order that the quality of the fiber produced in one field may not be mingled with the fiber of a different quality produced in a field of another soil type in the same locality.

It is commonly asserted by experienced flax growers that flax should have a medium-heavy soil for the best results. It will grow on very light soils, but the yields are usually low because of lack of moisture in dry weather and other physical soil relations. A medium-heavy soil that is well drained is ideal for fiber flax. Good drainage is necessary, as the soil must be worked early in the spring, and the

young plants will be killed if water stands on the surface after a heavy rain. Light soils and very heavy soils sometimes produce good crops of fiber flax, but they are more uncertain than the medium-heavy soils or silt loams. Light loams underlain with a clay subsoil retaining moisture during droughts have given good results with fiber flax. A sandy soil stores very little moisture and therefore does not supply sufficient moisture in time of drought.

The growth is abundant on muck soils that are common in the flax-growing section near the Great Lakes. The straw yields are extremely high, but the very succulent growth produced is usually associated with large plant cells, and the fiber is coarse and lacks strength. Potash and phosphorous fertilizers may improve the quality as well as increase the yield of flax fiber grown on such soils, but this may make the cost of production too great for reasonable profits.

On heavy soils that are likely to form a hard crust, flax should be planted as early as possible. The early rains will then prevent a crust from forming before the seedlings emerge and begin to grow. After the flax has started it will shade the soil so that it will be less likely to bake and form a crust.

The field selected should not be the poorest on the farm, one that will grow only weeds, but should be one of good fertility. Some scutching-mill superintendents in the United States protect their interests, as well as those of the farmer, by having an agreement before the flax is planted that it will be planted on a specific field known to have given good results with other crops.

PREPARATION OF THE SEED BED

After the first important step of selecting the land, the next step, of equal importance to the success of the crop, is to prepare a good seed bed. Generally, fall-plowed land is used, except perhaps in the Willamette Valley of Oregon. There, if the farmers plow their fields for flax in the fall, the heavy rains that occur during the winter months pack the plowed field, and by spring the soil is possibly in a poorer condition for aeration and hence colder and less productive of bacterial growth than spring-plowed land. Statistics secured in Oregon from numerous flax fields have indicated that early winter or spring plowing has produced greater yields than fall plowing. However, it is advisable in Oregon to plow in January and February, if the weather permits this practice, as fields plowed at that time allow earlier sowing of flaxseed in the spring.

Fall plowing allows the early working of the land in the spring and eliminates the delay that would be occasioned by spring plowing. Fall plowing also destroys many weed seeds and leaves the plowed soil in a better physical condition where freezing and thawing occur during the winter. The land should be thoroughly worked up in the spring to make as fine a seed bed as possible. Disking to begin with, followed by the harrow and a cultipacker, makes a firm seed bed and at the same time leaves the surface somewhat loose. Spring plowing may have to be resorted to when fall plowing is impracticable. In such a case the ground should be worked with equal care, and the bed made as firm as possible. The European farmers are said to make their flax fields as smooth and fine as a garden before planting. This is not altogether folly, since one should remember that in fiber flax

the uniform growth of the straw, and not the seed produced on the straw, is the important point, although the seed is a very important source of income. To obtain fiber of high quality and uniformity, it is necessary that all the stems be as nearly equal in diameter and length as possible. This cannot be accomplished if, at planting time, big clods make the ground rough and cause a nonuniform stand of plants.

It is doubtful whether too much emphasis can be placed on the importance of a firm seed bed. A cultipacker or roller will not harm a loose soil and will usually give good results by removing all the air pockets which dry out the soil. While some of the flax roots may penetrate 3 or 4 feet into the soil, the greater number of feeding roots are close to the surface. These must be well established in a firm soil in order to get sufficient moisture and food, especially during droughts. The seed planted in a firm soil will not be planted too deep and will emerge very promptly.

Flax is likely to do very well after corn, if the cultivation of the corn has helped to control the growth of weeds. In the preparation of such land for flax it is not necessary to plow, but the land should be well disked in the fall. If the cultivation of the corn has left ridges, these should be worked down to make a smooth field. In the spring the land should be disked again and then harrowed to make a fine, smooth bed before planting. This method of preparing corn land seems to give good results.

ROTATION

In western Ontario sod land is almost universally selected for growing fiber flax. In eastern Michigan the same practice is commonly adhered to, but there flax often follows a cultivation crop. The cultivation kills the weeds, which is very desirable. In Oregon flax follows a cultivation crop sometimes, but there the mistake has been made of planting flax after flax. Flax should not be planted on the same land oftener than once in 5 or 6 years. If planted more frequently, diseases and weeds become a menace, greatly reducing the yields. Flax wilt, a disease resulting from planting flax after flax, first manifested its importance by lessening greatly the stand and in some cases completely killing all the plants. Today wilt-resistant varieties that partly overcome this condition are known, but wilt is only one of many diseases, and therefore flax should be rotated to avoid wilt and other diseases. Wheat most often follows a flax crop. The flax comes off early in the summer, and then the land may be plowed and prepared for sowing wheat in the fall. Sugar beets and many other crops do well after flax, provided the land is deeply plowed and well cultivated.

Cornfields or bean fields that have been kept free from weeds by cultivation are well suited for flax. In eastern Michigan, land that has been cropped with peas is very desirable. These fields are always fall-plowed or disked in preparation for flax. Flax rarely grows well after wheat, oats, or other small grains.

A rotation should be devised in which flax comes only once in 5 years. The following rotations are offered as some suggestions:

Sod, flax, wheat, corn, oats.
Sod, flax, potatoes, beets, corn.
Corn, flax, wheat, hay, pasture.
Corn, flax, a small grain, clover or alfalfa, clover or alfalfa.

FERTILIZERS AND LIME

It has not been the practice for farmers to use fertilizers for their flax crops. If they are used, they should be applied to the preceding crop, in order that they may be more uniformly mixed with the soil so the flax may have the resulting effect the second year. The danger in applying barnyard manure before planting flax is due largely to the possibility of introducing weeds. Fertilizers, even though they do not contain weed seeds, are seldom applied uniformly over the surface. The result is a streaked field due to an uneven growth of the flax. This is very often seen in grainfields, and while the results might give a good grain yield the straw produced will not be uniform. With fiber flax this nonuniformity of straw in diameter, height, and branching is to be avoided, because the flax stems must be as nearly alike as possible. Nitrogen fertilizers, while likely to increase the tonnage of straw, do not give a corresponding increase in weight of fiber. If nitrogen is applied it has little beneficial effect upon the fiber because of the tendency to make it coarse and weak. It is unwise to attempt to raise flax on poor land by fertilizing heavily. Little or no fertilizer will be needed if a field moderately rich in fertility is selected.

Flax does best on a neutral soil, and, therefore, an application of lime on acid soils may be beneficial. This should not be applied just before planting flax, but before some other crop in the rotation that might benefit from lime. A fresh application of lime to flax will produce a brittle, weak fiber and a straw with a lowered percentage of fiber. Lime applied 2 or 3 years before flax is sown seems to have a beneficial effect and does not lower the quality of the fiber.

Muck or peat soils, although not used to any great extent in growing fiber flax, may require an application of potash or phosphoric acid to produce good fiber, but this may prove too expensive to leave a margin for profit.

It was formerly thought that flax was injurious to the land. This has been sufficiently disproved, as flax takes even less food from the soil than many of our common crops. However, flax land should be plowed deeply for the next crop in order to turn up new soil, as flax obtains most of its plant food near the surface.

PLANTING THE CROP

TIME TO PLANT

The time of planting flax is one of the very important factors in its success. Nowhere in the United States is this more true than in Oregon, where the normal dryness during summer months, beginning with June, stops the growth of the flax, and unless a good growth has been attained before these dry months begin the flax is likely to be a failure and produce only a very short harsh straw. Since the young flax plants will endure a few degrees of frost, it is possible to plant the seed very early. It is also important to plant early because the seedlings are benefited by the early rains and cool spring weather. Cool, moist weather in the spring is ideal for fiber flax. The plants will grow quickly and be well advanced in growth before the warmer and drier weather of June and July arrives. By this time the plant has made its growth and is at a stage to begin to produce seed.

Fiber flax should be one of the first crops planted in the spring. It may be planted at the time of sowing oats or barley. A week's

difference in the time of planting will usually make a big difference in the yield of straw and fiber (fig. 1). This is especially so in years when there is a late spring. In most cases the unthreshed straw is sold to the scutching mill, therefore, the heaviest crop possible is desired. If planted early, fiber flax will get a growing start ahead of the weeds and thus better withstand their competition. Late sowings of flax are usually weedier than early sowings. Early-sown flax is more likely to escape injury from flax wilt and rust, since these diseases are more virulent in midsummer or later.

To illustrate the advantages of early planting in Oregon, the yields from the experimental plots at the Oregon Agricultural Experi-

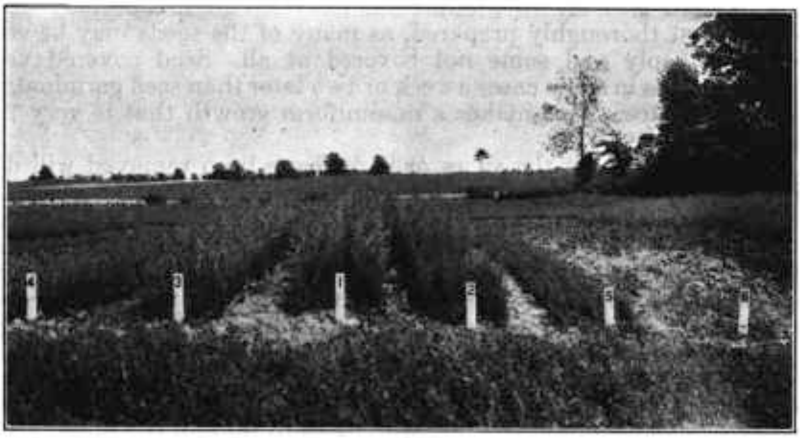

FIGURE 1.—Effects of early and late planting. Plot no. 1 was planted as early as the soil could be well prepared. Plots nos. 2, 3, 4, 5, and 6 were planted about a week apart, in the order named. At full maturity the late-planted fiber flax rarely equals that of the early plantings.

ment Station in 1932 may be cited. Flax was planted first on April 11, which was not considered early, and yielded 3,000 pounds of unthreshed straw per acre. Flax planted 1 week later yielded only 64 percent as much as the first planting; flax planted 2 weeks later yielded only 46 percent as much; and that planted 3 weeks later yielded only 14 percent as much. Table 1 shows the advantages of early planting in Michigan. The figures, however, may be considered as indicative of probable yields in many sections of the United States where fiber flax might be grown.

TABLE 1.—*Acre yields of threshed straw and seed of flax planted in different years on different dates at East Lansing, Mich.*[1]

Time of planting	Threshed straw						Seed					
	1926	1927	1928	1929	1931	Average	1926	1927	1928	1929	1931	Average
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
April, third week	------	2, 400	------	------	1, 846	------	------	568	------	------	314	------
April, fourth week	------	2, 300	2, 763	------	1, 309	------	------	543	354	------	165	------
May, first week	4, 039	2, 350	2, 481	1, 881	1, 930	2, 536	890	501	293	505	212	480
May, second week	3, 975	2, 362	2, 036	1, 904	1, 440	2, 343	824	534	225	455	147	437
May, third week	2, 412	1, 600	2, 316	2, 100	1, 143	1, 914	537	359	207	318	101	304
May, fourth week	3, 341	519	2, 301	1, 128	1, 176	1, 693	342	99	166	59	28	139
June, first week	------	------	1. 376	1, 627	------	------	------	------	56	51	------	------

[1] No test was conducted in 1930.

METHODS OF PLANTING

The old method of planting flax was to sow the seed broadcast by hand, and fair results were obtained by a skilled sower. Much of the flax in Europe is still sown in this manner. There, however, the seed bed is usually prepared much better than in the United States, where farming is less intensive. Hand sowing is employed very little in North America today, partly because the art of sowing in this manner has been lost to the present generation but chiefly because of improved machinery. From broadcasting by hand the next step was broadcasting with machines. Many farmers in the United States plant with a broadcasting machine and later cover the seed with a harrow or float. This method is likely to produce an uneven stand, especially on a seed bed not thoroughly prepared, as many of the seeds may be covered too deeply and some not covered at all. Seed covered very deeply emerges in some cases a week or two later than seed germinating near the surface. This makes a nonuniform growth that is very undesirable.

A drill from which the shoes or disks have been removed will distribute the seed more evenly than if the sowing is done by hand. On very well-prepared seed beds, such a drill may be followed by a float or drag, which gives good results. However, the average farmer is so rushed that his seed bed is not usually prepared as well as it should be, and there are clods and depressions in the surface that make the seeds lie at uneven depths if merely scattered upon the surface. Therefore, it is desirable that the seeds be distributed evenly over the field as well as covered to a uniform depth. This work is done best on a firm seed bed with the ordinary grain drill. The drill will distribute the seed evenly and cover it at a uniform depth so that all the plants have an equal start at germination. Most grain drills have feed tubes 7 inches apart, but there are clover and alfalfa drills in which the feed tubes are only 4 inches apart. Such a drill is better, as the seed is more evenly distributed although sown at the same rate per acre. One advantage in drilling is that if the seeds are accidentally placed too deep, the seeds lying side by side have a combined effect upon lifting the soil and pushing their way to the surface. The greatest disadvantage in drilling flax occurs on loose seed beds, where some seeds are likely to be covered too deeply where the drill sinks in the loose seed bed. The seeds should not be sown deeper than 1 inch, and a depth of one fourth to one half an inch is preferable. Figure 2 illustrates the advantage of ½- and 1-inch plantings over 1½- and 2-inch plantings.

RATE OF SEEDING

If flaxseed is broadcast by hand or by machine a little more seed should be sown than if a drill is used, as the distribution is likely to be less uniform and a smaller number of plants may emerge. With a drill, excellent results may be obtained by sowing from 75 to 85 pounds of good seed to the acre. A very common rate is 84 pounds, or 6 pecks, to the acre. The yields may be higher with heavier sowing, but there is danger of the flax lodging, especially the tall-growing varieties that give the best fiber. If the flax lodges badly there is the added difficulty of harvesting, and in all probability it will have to be cut for upholstery tow and sold at a lower price than if sold for spinning fiber. Lodged flax tends to mold in warm, damp weather; mold injures the seed

and fiber and lowers the yields. In sections of the country where flax does not often lodge, it may be safe to seed at a little heavier rate, but this must be determined by trial in each section.

SEED

SELECTION

Only seed that has been thoroughly cleaned and thus freed from all light, shriveled, scaly, or diseased seeds should be planted. If the seed is not in this condition when purchased, it should be cleaned by being run through a fanning mill. This is important not only to remove the light seeds but also to remove weed seeds and small particles of straw and chaff that may be present. Rust, a flax disease, is carried on particles of straw, and these should be eliminated. If the seed is clean it will probably germinate well. However, in buying seed it is best to have a guaranty that the germination is of a high percentage.

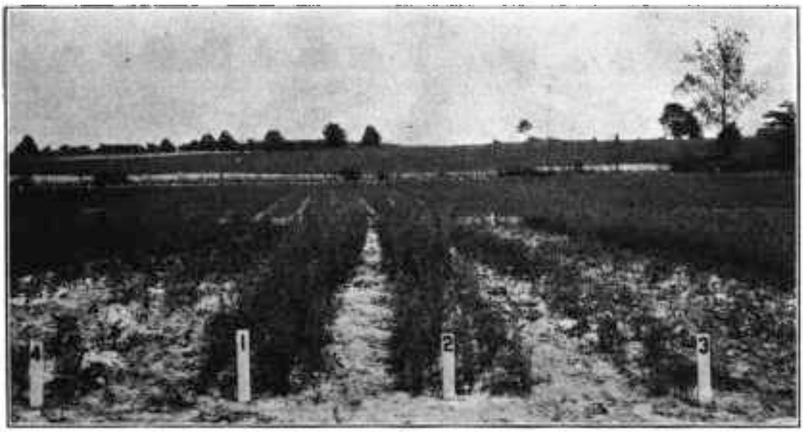

FIGURE 2.—The effect on the stand of planting flaxseed at different depths. The seed was planted ½ inch deep in plot no. 1, 1 inch deep in plot no. 2, 1½ inches deep in plot no. 3, and 2 inches deep in plot no. 4.

Flax for fiber is harvested early and, therefore, often has many immature seeds. If these are not removed in fanning, the rate of germination may be low and the seedlings weak. The germination should be 95 to 100 percent and the seedlings strong and sturdy in appearance. The period of germination is short, usually 3 to 4 days if the weather is warm.

The majority of the farmers plant the seed furnished under contract by the scutching mills. It should be well cleaned at the mills before coming to the farmer, as he seldom has time or facilities for cleaning it properly. Only the heaviest seeds should be saved for planting; those of light and medium weight should be sold to a linseed-oil mill. So far as possible, seed for planting should come from fields known to be free from rust or other diseases.

VARIETIES

In the past most of the seed that has been planted for a fiber crop has been imported from the Netherlands or Russia. This seed has

been planted in the United States from 1 to 4 consecutive years, usually only 3, and then new importations have been made. These imported seeds do not represent pure varieties but are designated only by the region from which they come. For example: White Blossom Dutch and Blue Blossom Dutch seed come from the Netherlands; Riga, Pernau Crown, Esthonia, Kostroma, Pskov, and Latvia seed come from Provinces in Russia or countries around the Baltic Sea. In some instances seed of fiber flax goes by the name of the exporting company. In the last few years the United States Department of Agriculture and experiment stations in different parts of the world have been breeding and selecting fiber flax to obtain pure varieties, some of which are now for sale in the United States. These varieties, such as Pinnacle, Lirals, J.W.S., and Texala, give different yields of fiber and seed in different sections of the country. Information as to sources of reliable seed may be obtained from the experiment stations in States where fiber

FIGURE 3.—Variety test of fiber flax conducted under the supervision of the United States Department of Agriculture. White-blossom varieties are in full bloom, while the blue-blossom varieties have nearly finished their flowering period. This shows the characteristic lateness of white-blossom flaxes.

flax is grown. Figure 3 shows a variety test conducted under the supervision of the United States Department of Agriculture at a State experiment station.

With mechanical methods taking the place of hand methods in harvesting and in preparing the fiber, it is of increasing importance to grow improved strains that produce plants of greater uniformity.

Experienced growers of fiber flax will undoubtedly say that seed should be imported each year. This, however, is not necessary if a good variety is obtained. Results have shown repeatedly that the pure varieties of fiber flax adapted to the different sections of the United States will compare very favorably with any imported seed over a number of years. The commercial imported seed may not be of pure strains and may tend to degenerate after 2 or 3 years, after which a new importation will have to be made, but if proper precautions are followed the pure varieties will not deteriorate.

There is always danger, when importing seed from foreign countries, of bringing in plant diseases on the flax seed or on the small particles of flax straw contained in the seed. Because of the danger of bringing

in new plant diseases and the fact that good seed may be obtained in this country, it is recommended that importations of foreign seed be avoided.

GROWING SEASON

The growing season for fiber flax is very short, ranging from 85 to 100 days, and the plants mature more quickly if the weather is warm and dry. The seed germinates quickly and usually well. After the young seedlings are an inch above the ground they seem to grow very slowly for 2 to 3 weeks, and then if the weather is favorable they make a more rapid growth until blossoming. During this rapid period of growth the flax requires no care, being treated in the same manner as a grain crop. If weeds are troublesome it may be necessary to pull out those making a large growth. If weeds are removed it should be done while the flax is only a few inches high, as at a later time some of the flax will be trampled down and some pulled up in any attempt to remove weeds.

The plants begin blossoming when they are 55 to 65 days old. The blossoming period is short unless prolonged by cool wet weather. The flowers open early in the morning, and the petals begin to fall about 9 or 10 o'clock, or as soon as the sun becomes hot, but if it is cloudy the petals may remain attached all day. The fields of flax are very pretty at full bloom, a mass of blue or white blossoms, depending upon the variety sown.

The white-blossom varieties are usually 7 to 10 days later in maturing than the blue-blossom varieties. In a locality that has a very short growing season, such as the Upper Peninsula of Michigan, the late-maturing varieties would be objectionable. The white-blossom varieties are grown very little in the United States because they produce a coarse fiber. This is the case with imported white-blossom seed, but it usually produces more seed than the blue-blossom varieties.

IRRIGATION

Fiber flax is not grown under irrigation except in a limited area in Egypt. The surface soil must have good drainage and be well plowed and even on the surface. No water should be added after the plants begin to blossom, as it will only tend to prolong the blossoming period and may cause a second growth, making the fiber of lower quality and the work of scutching more difficult. The soil should have sufficient moisture to germinate the seed, and when the flax begins to grow rapidly moisture is most important. This period will last about 5 to 6 weeks, and during this time, under favorable conditions, an additional growth of 24 to 30 inches may be obtained.

Fiber flax in irrigated fields and in low, moist spots in nonirrigated fields is more susceptible to rust than that in drier fields. The moist places are more favorable for the development of rust. Flax wilt also tends to be more severe in damp fields. On irrigated land or low, damp ground it is especially important to practice rotation and to plant clean seed of disease-resistant varieties.

Fields with uneven surfaces, having low spots that collect water during the irrigation, should be avoided or corrected if possible. The damp areas will tend to prolong the maturing, and the whole field will not be ready to harvest at the same time. Overirrigation should be avoided at all times.

WEEDS AND TRASH

Nearly all contracts with farmers contain a clause permitting the flax-scutching mill to dock the price in case of an excess of dirt, trash, or weeds in the flax when delivered. Dirt is more troublesome in years when the season is wet at harvest time, as small clods of dirt cling to the roots when the flax is pulled. Some of this may be shaken off in pulling, but a small percentage by weight of dirt will go to the scutching mill.

The farmer who plants his flax on clean land has no fear of weeds being troublesome. Prices are rarely docked for flax produced by careful farmers, but the shiftless man who believes that he can produce this cash crop upon his poorest and weediest land often meets with failure. In the production of upholstery tow, weeds are less objectionable, but even for this coarse product it is better to have clean flax straw.

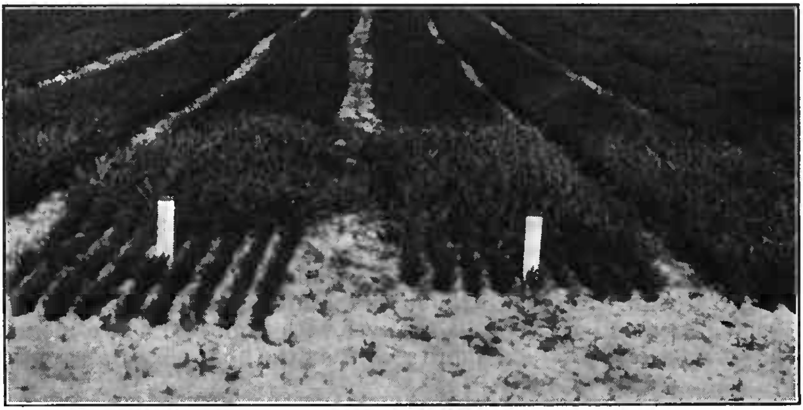

FIGURE 4.—Quackgrass coming up in fiber flax on Government experimental plots. The flax cannot compete with a weed as vigorous as this.

Mechanical pullers, fortunately, do not pull many big weeds but merely strip off the upper leaves. In hand pulling, the weeds unless too numerous may be avoided, but this takes more time than would be necessary to clean the land well before planting. Small areas containing weeds, such as that shown in figure 4, are nearly a complete loss at harvest.

Large weeds, including Canada thistle, dock, mustard, falseflax, dogfennel, French pink, and the twining vines such as dodder, species of morning-glory, bindweed, wild buckwheat, and the grasses, quackgrass, foxtail, barnyard grass, and chess, are especially undesirable. Weed seeds may be present in small amounts that are difficult to fan out of the flax seed. Some of these weed seeds are seeds of French pink, falseflax, foxtail grass, and wild buckwheat.

The best means for fighting weeds in flax is to plant clean seed on weed-free land at an early date. If this is done and if conditions of soil and climate are favorable, the flax will hold its own against weeds.

DISEASES

Flax is subject to a number of diseases, but only 2 or 3 have ever become very widespread in fiber-flax fields of North America. Some of the others have caused serious losses in seed flaxes, but are apparently unknown in some of our oldest fiber-flax regions. This may be partly due to the fact that they have been present but have been overlooked or mistaken for other diseases. That is not so probable in the last 10 or 12 years, since flax diseases have been studied more carefully.

In general, to combat diseases the farmer should plant disease-resistant varieties if obtainable. The seed should be thoroughly cleaned of all trash and light scaly seeds, as these are the principal carriers of disease. All of the diseases of flax have been introduced

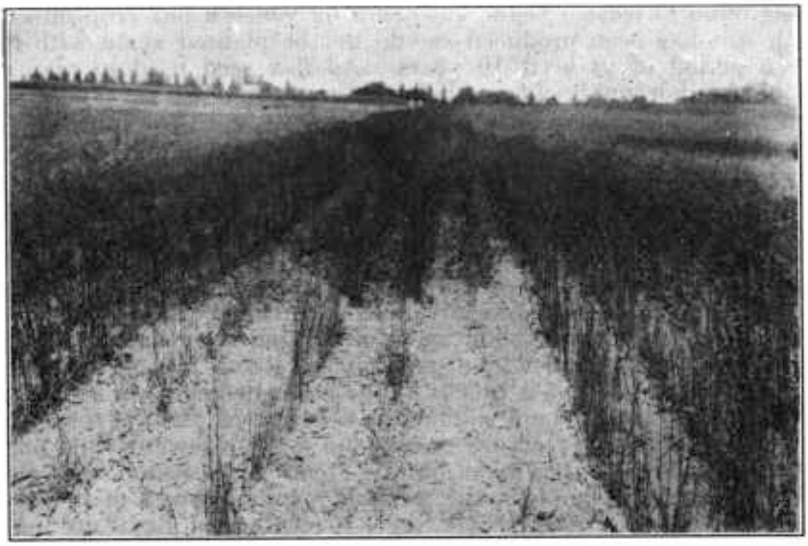

FIGURE 5.—Plot showing resistance and nonresistance to flax wilt. The plants of some varieties are all killed by wilt; in other varieties, nearly all are killed; and in still others, the plants are not affected.

with seed imported from other countries. There is much less danger in using seed from known sources in the United States. Plant early on land not previously cropped with flax and harvest early.

FLAX WILT

Flax wilt has been one of the most destructive diseases, destroying the entire crop in some fields and reducing the yields in other fields. In the last few years this disease has not been very destructive in Michigan and in Oregon, because the flax has been grown on new land or in fields that have not been in flax recently. Tests have indicated that fiber flax is more resistant to wilt than seed flax, but this has not been definitely proved under all conditions. There is, however, always the danger that imported flax seed may produce a crop especially susceptible to wilt, which will result in loss. Several State experiment stations have shown that the plants from imported seed are more susceptible to wilt than the varieties that have been bred and distributed in North America. Figure 5 shows a wilt test conducted upon several varieties, some of which are susceptible to the disease.

The disease is caused by a fungus, *Fusarium lini*, the spores of which remain in the ground and attack the roots. This results in a gradual dying out of the plants. The plants may be affected at any stage in their development, and some plants although attacked by this disease continue to live and produce some seed. The leaves turn yellow beginning at the tips, the plants wilt, the heads bend over, and the plants soon die. The diseased roots are ashen gray, but under the epidermis they are yellow, while the normal color is white. The disease may appear only in spots, but if flax should follow flax the whole field soon would be infected. The best methods for control of the wilt disease consist in growing wilt-resistant varieties and practicing rotations in which flax comes only once in 5 years. The spores of the fungus causing flax wilt are known to remain alive in the ground at least 5 years, and fields on which a flax crop infected with wilt has been produced should not be planted again with flax for a period of at least 10 years. All flax seed used in planting should be thoroughly cleaned before it is sown.

FLAX RUST

Rust of flax, caused by a moldlike fungus, *Melampsora lini*, is one of the oldest known diseases of the flax plant, and it occurs in nearly every region where the flax is grown. It multiplies by means of minute spores, and these must be present with favorable conditions of moisture for flax to become infected. Fiber flax is usually harvested before the disease has advanced to the most destructive stages, and only a few orange-yellow spots of varying sizes may be seen on the leaves and stems. These spots on the stems, if large and deep, injure the fiber so that it breaks at the weakened spots in scutching. This is likely to result not so much in a decreased yield of total fiber as it is in a larger percentage of tow and hence a lower selling price.

In cases where large areas on the stems are infected with rust, sometimes the whole stem, the result is a complete loss of the fiber. However, it is not often that a larger percentage of stems are found in this condition, especially with the improved varieties. An infection of rust is often said to be associated with good flax years and, therefore, looked upon with favor by some, but the relationship of the intensity of the rust and good yields is partly the result of more moisture than in other years.

Orange-yellow roundish pustules, or spots, first appear on the leaves and stems, and later in the season elongated brown to shiny-black spots appear on the stems. The blackish spots seldom appear much before harvest time, and if the flax is harvested early it may escape serious injury. As far as is known at present, no commercial variety of fiber flax is entirely immune to flax rust. Some varieties, however, are much more severely affected than others, and it is advisable to plant the best seed obtainable which is resistant both to rust and wilt. The disease is carried to the field on small bits of stems, leaves, and chaff not cleaned out in the fanning mill. Therefore, special care should be taken in the cleaning. It is best to plant seed from fields known to be free from flax rust.

PASMO

Pasmo, or rust blotch, is a very serious disease first recognized in the United States in 1920. It is caused by a fungus, *Phlyctaena*

linicola, first discovered in Argentina in 1909. It has been very destructive in limited areas at 1 or 2 local points in fiber-growing sections, but so far it has not become general. The disease appears shortly before harvest. It may be recognized by characteristic yellow to brownish mottled areas upon the stem, leaves, and capsules. The discolored areas grow larger and may eventually cover the whole stem. Green patches between the yellow-brown areas make the disease more easily discernible. Planting seed of varieties resistant to pasmo and harvesting early, in case the disease is present, are recommended as the best methods for controlling the disease. The seed from crops known to be infected with pasmo should not, under any conditions, be used for planting.

CANKER

There are two kinds of canker; one, anthracnose, caused by a fungus, *Colletotrichum linicolum;* and the other, heat canker, caused by high temperatures at the surface of the soil. Neither kind is common in the fiber-growing regions. Anthracnose is recognized by lesions or spots on the leaves and stem, which produce a girdled effect or appearance. Heat canker girdles the young plants at the soil line, causing them to break off. Early seeding on land not likely to crust is the best control for heat canker, while anthracnose may be avoided by planting clean and plump heavy seed.

HARVESTING

TIME

The time of harvesting is an important point in growing fiber flax, but one in regard to which the grower may be helped by the millman. The scutching-mill company that contracts for the flax should be ready to advise the farmer when to harvest, as sometimes it furnishes the machine for harvesting.

Fiber flax is harvested at an earlier stage of maturity than seed flax, but the seed is saved from fiber flax in practically all countries where it is grown except in Ireland. The seed rarely ripens well enough in the continuous cool, moist climate of Ireland to make it worth the extra work of saving it. If harvested too early, the fiber will be very fine and silky but lacking in strength and low in yield. If allowed to become ripe enough for a maximum yield of seed, the fiber will be coarse, harsh, and brittle, with poor spinning qualities.

A good yield of seed may be secured if the flax is harvested when one third to one half of the seed bolls are brown or yellow, with fully developed hard brownish seeds. At this time the stems have usually turned yellow and the leaves have fallen off the stems two thirds of the distance up from the ground. If cut or pulled at this time the immature seeds will ripen on the plant in the shock and the yield will be nearly as large as if they were harvested later. The fiber also will be of much better quality, having retained much of the "nature" or spinning properties that are lost if the plant is permitted to become too ripe.

Short flax and lodged flax, either of which is likely to be used for upholstery tow, should be harvested last, as their value is not as great as that of erect, long-stemmed flax that will produce a high-

priced spinning fiber. There are localities where fiber flax is being raised only for upholstery tow, and for this purpose the exact stage of harvesting is less important. Flax seed is an important byproduct in the preparation of upholstery tow; therefore more mature crops are preferred for this purpose, but not those ripe enough for the straw to be brittle.

If there is rainy weather at harvest time the flax is likely to make a very undesirable second growth. This happens after the plant has matured and turned yellow. It will turn green again and begin to blossom a second time. This may cause the plant to branch, which injures the fiber. A second growth in flax will result in fiber of much lower grade for spinning. It is better to harvest at once if second growth starts. This growth will add no weight to the final amount of fiber obtained, as it is a growth of seeding branches and wood. The plants become more woody and are much more difficult to scutch.

METHODS

HAND PULLING

Pulling by hand is still practiced in most of the fiber-flax-growing sections of Europe. Labor there is cheap, and the men, women, and children are accustomed to the work. In western Ontario most of the Canadian fiber flax is grown near an Indian reservation, and the Indians do the pulling. The Indians camp right in the field, and the women and children help in the pulling.

A few years ago the fiber flax in the United States was pulled by hand, but now it is difficult to get men to do this kind of work. It is indeed tiresome work the first day, but one quickly becomes accustomed to it. The amount pulled in 1 day depends upon the ability of the worker, but varies from one-eighth to one-fourth of an acre per day. In 1928 Oregon flax growers paid as high as $25 per acre for pulling flax by hand, but even at this price, it is difficult to get men to do it. However, in 1932, owing to the scarcity of work it was possible to find many laborers who were willing to pull flax by hand in Oregon for $10 per acre, and flax was pulled by machines under contract for $4 per ton. If flax-pulling has to be done by hand it is very unlikely that an extensive fiber-flax industry can be developed in the United States.

MACHINE PULLING

Many machines for pulling fiber flax have been devised in the last 20 years. A dozen different kinds have been built, and some of them have been used in the fields. The machines have steadily improved until now there are 1 or 2 on the market that do pull flax fairly well (figs. 6 and 7). Still further improvements are necessary for really satisfactory work. In 1923 the Vessot pulling machine was introduced into Oregon, and the number of machines has been increased each year. These machines have been improved each year, and the price has decreased. There have been breakdowns and delays in pulling, owing to imperfections in the machines, but in the end the machines have pulled practically the entire flax acreage in Oregon. There are 1 or 2 other flax-pulling machines on the market that have not been tried out in the United States. Possibly in the future these foreign pulling machines, which are cheaper in price and much simpler in construction and operation, may be tried out in the United States.

MOWING

If upholstery tow is being produced, mowing offers an excellent and inexpensive method for harvesting the crop. The flax is mowed down at the rate of 4 to 6 acres per day and allowed to cure on the ground several days before being hauled to the mill. Fibrous

FIGURE 6.—One type of flax puller in operation. The pulling device on this machine is driven by a gasoline motor that is attached to the side of the machine.

FIGURE 7.—Flax fields in Oregon that were harvested by a machine puller. The pullers, when working well, get all the flax, as is shown by the cleanness of the field.

flax plants are tougher and harder to cut than grass, and it is important to keep the knives sharp and the bearings of the machines well oiled. The knives should be replaced by sharp ones every 3 hours or even oftener if the flax is overripe and some of it dead,

because in this condition the flax is very tough. There is occasional trouble from the mower becoming gummy and hard to operate. This gum may be removed readily with kerosene or gasoline. A type of mower used extensively in eastern Michigan for harvesting flax for upholstering tow is shown in figure 8.

THRESHING

In the production of upholstery tow the threshing offers no problem, since the machine making the tow also does the threshing, and the seed is cleaned afterward by a fanning mill. For the production of line fiber, flax is threshed before it is retted. In some cases the flax is retted with the seed still on the straw. This results in a partial loss of the seed or in most cases where this is practiced, as in Ireland, there may be very little seed worth saving. The common method of threshing fiber flax, both in the United States and in western Europe, con-

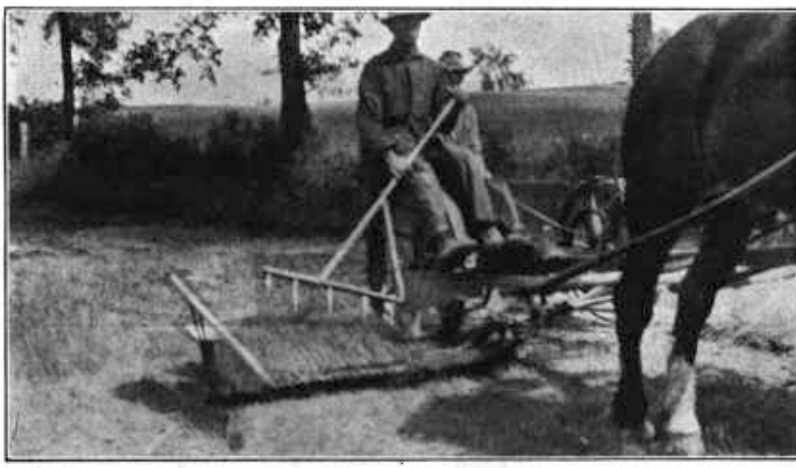

FIGURE 8.—Type of mower best adapted for cutting flax for upholstery tow. One man drives the team and the second man rakes the cut flax off from a platform in small bunches.

sists in passing the seed-bearing portion of the straw 3 to 5 times between smooth revolving rollers pressed together by springs (fig. 9). The straw is not injured, and the seed bolls which are crushed, fall off. This method, while effective upon small bundles of hand-pulled flax, involves much hand labor in untying the large bundles of machine-pulled flax before they are threshed, and retying them after threshing.

There are machines in Europe designed to thresh flax with less hand labor, but they are still more or less in the experimental stages and are not used in many factories. Their practical application has not been demonstrated in North America. The straw must not be broken, as it would be in passing through a grain separator, because uniform retting would then be impossible and the fiber produced would be suitable only for upholstery tow.

If dew retting is practiced the flax may be moved from the shock to the threshing machine, and after threshing the straw is spread on a field to ret. Where tank retting is practiced the flax may be stacked as shown in figure 10 or, better, stored under sheds as shown in figure

11. It may then be threshed as fast as the straw is needed to fill the retting tanks or threshed and stored again to await retting. The retted straw, when dried, should be put under a shed until scutching time.

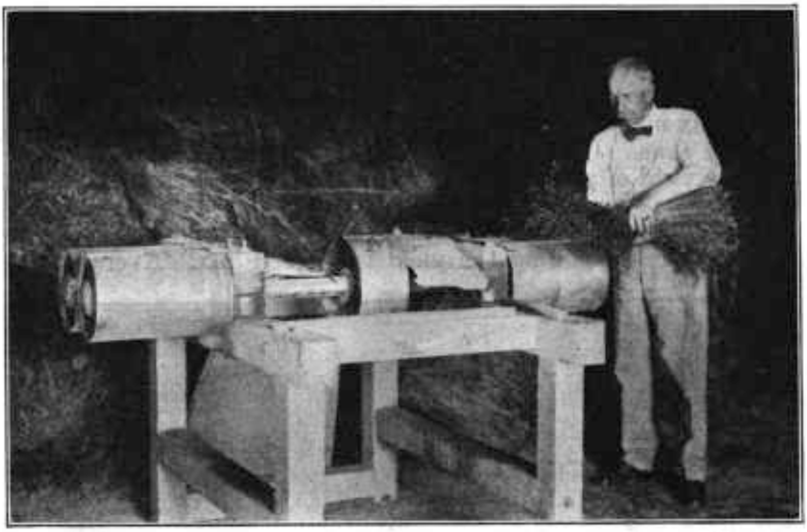

FIGURE 9.—Fiber-flax threshing machine. The bolls, or heads, are passed a few times between the revolving-belt pulleys, which are pressed together, crushing the seed bolls.

FIGURE 10.—Fiber flax, after being cured in shocks in the field, is drawn to the scutching mill and stacked until it can be threshed and retted.

YIELD

The yield per acre of fiber flax may be stated in several different ways. For example, unthreshed straw, threshed straw, line and tow fiber, and seed. If the fiber flax is being grown entirely for green or

upholstering tow, it is customary to mow the flax, and this flax (when well cured) will yield about 1½ tons per acre. Often only the poorest fiber-flax fields, which will not produce a good spinning fiber, are mowed and used for the production of upholstering tow, and in such cases the yield of mowed, unthreshed straw will probably average less than 1½ tons per acre.

Most of the fiber flax used for the production of fiber for spinning is pulled either by hand or by machine, bound in bundles, cured in shocks, and drawn from the shock directly to the scutching mill. The yield of flax in this form ranges from 1 to 3½ tons per acre, averaging about 1¾ tons. Under favorable conditions and on well-managed farms the yield of pulled, unthreshed straw may reach 3 tons or more per acre.

The yield of seed from different varieties of fiber flax varies, in some instances nearly equaling the yield from seed flax. Average yields,

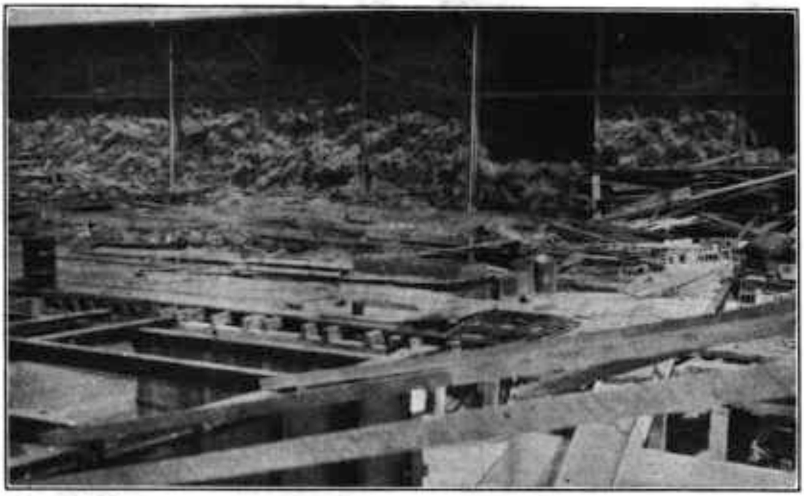

FIGURE 11.—Large, open, inexpensive sheds are used for storing pulled flax. It remains there until taken to the retting tanks. Single sheds are built to hold 500 to 600 tons of flax straw.

when the seed has been sown at the rate of 70 to 85 pounds per acre for fiber production, range from 5 to 10 bushels per acre. Thinner seeding gives a higher yield of seed and lower yield of fiber. The yield of seed will also vary with the variety and with conditions of soil and climate. Generally the flaxes yielding the most seed yield the least fiber.

The yield of fiber flax in different stages, as produced in the United States, may be stated roughly as follows:

Pulled flax in bundles, unthreshed, as usually sold by the growers, 1 to 3½ tons per acre, averaging about 1¾ tons.

Threshed flax, before it is retted, after losing 33 to 35 percent of seeds and chaff, about 1⅙ tons.

Retted straw, after it has been dried and has lost about 16 percent in retting, 1 ton.

Scutched fiber, including tow, after losing about 80 percent in scutching, 400 pounds.

Seed varying from 5 to 10 bushels per acre averaging about 7½ bushels.

PRODUCTION OF UPHOLSTERY TOW

In the production of upholstery tow the fiber-flax straw is not retted. The unretted flax straw is crushed so that the fiber separates from the woody part of the stem. The fiber produced in this manner is used in upholstered furniture, car seats, and automobiles, and is known as upholstery or green tow to distinguish it from the tow prepared for spinning. This industry seems to pay fair returns. In unfavorable years when all fiber flax is short, the companies ordinarily producing fiber for spinning cut a large proportion of their flax for upholstery tow. This increases greatly the amount of green tow offered for sale and lowers the price of all upholstery tow. In such a year a company that usually manufactures only upholstery tow from fiber flax has greater competition in a market oversupplied with this high-grade tow. The mills making green tow from fiber flax must always compete with the mills in Minnesota making tow from seed-flax straw, but this competition is not very great because of the difference in quality between the two products.

For several years after the World War fiber-flax upholstery tow commanded a price nearly twice as great as the western seed-flax tow. However, during the depression years of 1932 and 1933 fiber-flax upholstery tow was offered for sale on a much narrower margin over seed-flax tow than formerly.

This industry, while not extensive, is probably sufficient to supply the limited demand for good-quality tow. It requires very little hand labor, and no retting, scutching, nor threshing of the straw by expensive methods. Weeds and diseased straw, while objectionable, do not cause as much loss in upholstery tow as they do in fiber for spinning.

In common practice a company operating an upholstery-tow mill furnishes the seed to the farmer who does the planting. At harvest time the farmer cuts the flax with a machine, also furnished by the company, and after a few days hauls the cured straw to the mill, where he receives cash for his crop. It is purely a cash crop for the grower, and one of the earliest cash crops produced. It requires little outlay of money, but it does not often bring large profits.

Usually 3 tons of flax straw are made into 1 ton of upholstering material. In 1932 and 1933, owing to the low price that manufacturers were willing to pay for a high grade of upholstery tow, it was somewhat common to find mills making 1 ton of upholstery tow from 2 tons of straw.

The woody shives that are separated from the tow, or fiber, may be used for fuel. The mill, besides selling the green tow, makes a profit from the seed as a byproduct. The demand for good fiber-flax green tow, while not large, might be increased through a more thorough understanding of its use and value. In some cases it might be substituted for more expensive packings of wool and hair.

PREPARATION OF SPINNING FIBER

The farmer, or grower of fiber flax, delivers the straw at the scutching mill after it has dried in shocks in the field. The processes of preparing the fiber from the unthreshed straw requires special apparatus and must be carried on by men having skill and experience in this particular work in order to produce uniform fiber acceptable to flax spinners.

RETTING

The word "ret" means rot. Retting, therefore, is simply a process which dissolves certain gums in the plant that bind the fibers to the wood and destroys the thin-walled tissues surrounding the fibers. This may be brought about by bacterial action or by chemical changes. The bacteria that cause the retting or rotting of the straw are common soil bacteria and are present on the straw when harvested. They are present in all soils, so that one need not worry for fear the flax will not ret because of lack of bacteria. At present all flax produced in commercial quantities is retted by bacterial action. Two methods are practiced in North America, namely, dew-retting and tank- or water-retting.

In dew-retting, flax is spread on the ground where it has been grown or, preferably, on grass or meadows, where it is retted by molds and bacterial action induced by frequent rains or dews. Retting is usually completed in from 1 to 3 weeks, depending upon the weather. In moist, warm weather the action is more rapid and may require only a week or 10 days. In cooler or drier weather the retting is slower and may require a month.

In dew-retting it is important to have the straw spread evenly and very thinly on the ground, as the dew should get to all of the straw to secure uniformity. To facilitate uniform retting, the straw is sometimes turned during retting. This involves more labor and expense, but it may be well worth while if the straw is long and of good quality. Dew-retting is entirely dependent upon the weather and, therefore, uncertain. If continued wet weather prevents lifting the straw in the field at the proper time, it becomes overretted and of little value. In nearly all cases the product is not uniform, and the fiber must be sold at a price lower than that of water-retted flax.

Water-retting, or tank-retting, seems to give the best results under American conditions. This is also true under European conditions, as practically all of the better grades of fiber are produced by water-retting. The initial cost of building the tanks may be large, but the retting is then under control and not dependent upon the weather. Fiber of good quality and more uniform in color and strength may be produced with greater certainty.

Water- or tank-retting consists in placing the straw in wooden or concrete tanks which are then filled with water. The ret here is accomplished in 6 to 8 days if the water is free from impurities and kept at 80° F., which is the temperature best suited for retting. Sometimes the retting will require a greater length of time, owing to the fact that the straw may be particularly fine or small in diameter, and it may have been produced in a dry season and be very hard or woody, and so require more retting and more care in scutching to separate the fiber from the straw. All the straw in a tank is subject to the same amount of retting, due to the penetration of the water, and the water may be drained off from the tank as soon as the ret has reached a desired stage. The best retting is done where the water is kept under controlled conditions of temperature and circulation. The heat necessary for warming the water may be furnished by burning the shives obtained in scutching.

The water in the tank should be kept circulating to facilitate more even distribution of temperature and bacteria and cause a uniform ret. The circulation of the water is not begun until after the first

day, and this is said to allow the retting to start. When the circulation is started, water at the right temperature is forced into the tank at the bottom, causing an overflow at the top. The water that runs off at the top may or may not be again forced into the tank. It is best not to put too much of the old water back unless it is purified, since it contains waste materials that slow up the ret. In most warm-water retting factories, the water in the tank is circulated to a slight degree. The amount of fresh water that is added during the ret will govern to some extent the degree of acidity, the speed of the ret, and the harshness of the fiber. In retting tanks, where the fresh water is added slowly so that all the water in the tank is replaced once in 24 hours, the fiber is likely to be harsh but well bleached. It is more common to replace the old retting water only once during the entire ret, although possibly under certain conditions a tank will often become what is termed sour and the retting will not proceed any further until all the water has been discharged and a new supply added. Retting tanks built on the bank of a small stream are shown in figure 12.

FIGURE 12.—Retting tanks built on the bank of a small stream that furnishes the water. A flax storage shed may be seen in the background.

Numerous quick retting processes have been suggested, but thus far none of them have been efficient enough to be adopted in place of dew-retting and water-retting. The element of time in itself in these established methods is inexpensive, and they usually require less actual work than the quick retting processes advocated. Furthermore, the fiber produced by the quick retting processes has rarely met with the approval of flax spinners.

DRYING AFTER RETTING

Dew-retted flax is "lifted" in the field, taken up, and bound in bundles when the bark containing the fiber separates readily from the woody inner part of the straw. The bundles of retted straw are hauled to the scutching mill. If rainy weather should set in, there is

danger of some straw overretting before all of it can be lifted. Water-retted flax must be taken out of the tank and spread on the ground or "wigwamed" in a field to dry. Wigwaming consists in setting up each wet bundle of retted straw with the butt ends resting on the ground and these spread out so as to allow free circulation of air (fig. 13). In Oregon, where the straw is tank-retted and then wigwamed in the field, there is usually favorable weather during the summer months to dry the straw. The straw when wigwamed has the advantage that it is off the ground in case of unfavorable weather, and requires only a few hours of sunshine to dry. If rains occur during the retting season the wigwams should be made from small bundles in order to hasten drying. If damp weather is experienced only in the fall, then the area covered per ton of straw in the fall should be increased. Slow drying in warm weather may cause moldy straw.

FIGURE 13.—Fiber-flax straw, after being retted in water, is taken from the tanks and set up in "wigwams" to dry.

Drying is usually accomplished with little difficulty except in the fall, when cool weather and rains interfere with and finally stop the work. In order to control drying, several methods have been devised to dry the straw artificially. At present, to the writer's knowledge, none of these has proved successful enough to do away with air drying in the field. An efficient artificial drying method would make it possible to dry the straw all the year round, and retting would not have to be stopped at the beginning of cold or damp weather. Excessive heat in drying flax straw is thought to drive off the oil and cause a loss of "nature", without which the fiber has poor spinning quality.

BREAKING AND SCUTCHING

Breaking is the process that follows retting in extracting the fiber from the stem. It consists essentially in breaking the woody portions of the straw into fine pieces, called shives, and at the same time breaking these shives away from the fiber or loosening them so that they may be beaten off in the next process, called scutching. In the

United States and in western Europe breaking is usually accomplished by passing retted dry straw, a handful at a time, between fluted rollers. The fiber is strong and flexible enough to resist the breaking and comes through as a long unbroken fiber.

In the preparation of spinning tow on a large scale the retted straw is passed through a series of fluted rollers followed by a beating cylinder and usually a shaking device. The straw is so broken and shaken that the fiber comes out free from wood or shives. A few of the newer flax-tow machines are devised to produce a scutching action upon the tow. Scutched or "targed" tow for spinning is prepared by holding the fiber from tangled stalks against the revolving blades of a scutching wheel.

In the production of line fiber, separate machines are used for breaking and scutching. The straw is kept straight at all times and is first put through a small break and then scutched by hand or by machine. Hand-scutching is very expensive work in the United States. This work requires a skill that can be acquired only by experience, and in the United States it is difficult to find men having the necessary skill.

Several small combined breaking and scutching machines have been devised in recent years. They require less hand skill than the scutching wheels, and some of them produce well-cleaned fiber with little waste. Thus far the capacities of the machines have not been much greater than the capacity of the brake and scutching wheel. Improvements are being made in the machines, and with increasing efficiency and lower prices they may take the place of hand-scutching, as the hackling machines in the spinning mills have taken the place of hand-hackling in the scutching mills. Only in the past few years have large scutching machines been invented, which reduce the cost of scutching enough so that this process can be carried on successfully in the United States with our high prices for labor. These improvements came after the World War. These turbine-type scutching machines were first introduced into this country in 1928. Previous to the invention of these turbine-type scutching machines, one man could clean on a scutching wheel from 65 to 75 pounds of flax fiber per day. These new machines increased production per man approximately 200 to 350 percent and produced a fiber of much better quality. The better quality is mainly due to the fact that the amount of waste is not so great and that the next process of hackling, which is carried on in a spinning mill, does not cause so great a loss as hand- or wheel-scutching flax formerly entailed.

MARKETS

The grower of fiber flax in the United States sells the product at the scutching mill in the form of bundles of unthreshed straw, drawn from the shocks in the field. Flax to be used for upholstering tow is delivered at the scutching or tow mills loose like hay. These products are of too little value as compared with their bulk to be delivered beyond a short trucking distance. A hauling distance of 25 to 30 miles over paved roads is regarded as about the maximum that permits reasonable profits.

No quotations of flax fiber are published in the United States. The prices vary, depending upon the supply and demand. The range of

prices for the fiber is governed almost entirely by the Russian and Belgian prices.

There are 17 flax-spinning mills in the United States: 14 in New England, New York, and New Jersey, and 3 on the Pacific coast. These mills use from 4,000 to 8,000 tons of flax fiber each year. The quantities produced in this country, 150 to 350 tons per annum, are relatively insignificant as compared with the total supplies required. Most of the flax fiber used in the American spinning mills is produced in Russia, the Baltic countries, or Belgium. The flax-spinning mills on the Pacific coast use practically all of the fiber produced in Oregon and import some of certain grades for mixing to make standard uniform yarns. A modern spinning mill producing yarns or twines for the general market cannot depend on a single source of supply for fiber.

MANUFACTURED PRODUCTS

Flax fiber is spun into linen yarns of various degrees of fineness from 8 lea, 2,400 yards per pound, to 120 lea, 36,000 yards per pound. In the spinning mills of this country linen yarns are rarely spun finer than 40 lea, 12,000 yards per pound.

The straight-scutched fiber is hackled in the spinning mills mostly by large hackling machines, which comb out all of the short and tangled fibers and shives. The hackled or dressed fiber is further combed repeatedly by being passed through several drawing frames before it reaches the spinning machine, which twists it into yarn. It is spun either dry or wet, depending on the kind of yarn desired. In wet-spinning, the strand or roving of fiber passes through a trough of hot water just before reaching the spindle. The finest yarns are wet-spun.

Flax tow goes through a carding machine instead of being hackled, and is carded into strands of parallel fibers before being spun into yarn. Tow cannot be spun into yarns as fine as those made of line fiber.

Linen yarns are doubled and twisted into shoe thread, tailor's thread, sewing thread, tying twines, carpet warp, bookbinder's twines, fishing lines, twines for fishing nets, and thread for laces. The yarn is woven into crash, toweling, buckram, sheeting, pillowcases, dress linens, handkerchiefs, fire hose, airplane wings, and plain or damask tablecloths and napkins.

Special skill is required for spinning fine linen yarns, and also for weaving the fine yarns into fine linen fabrics. Practically all of this work is done in limited areas in Ireland, Scotland, northern France, and Belgium, where a high degree of skill has been developed by many generations of workers.

Upholstering tow, which may be regarded as a byproduct, is used for stuffing material in upholstered furniture and in automobile and railway car seats.

The seed of fiber flax is also a byproduct. That which is not needed for sowing goes to the crushing mills, where it is used in the same manner as seed of seed flax in the production of linseed oil for paints and varnishes and in linseed cake for stock feed.

The shives beaten out by the brake and scutchers are used for fuel to furnish steam for operating the machinery in the scutching mill.

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